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FURTHER STUDIES ON THE SPREAD AND CONTROL OF HOP MILDEW.

F. M. BLODGETT.

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F. M. BLODGETT.

SUMMARY.

1. Hop mildew first caused serious damage to hops in New York State in 1909, since which time it has gained steadily in importance and become a constant menace to the crop.

2. The perithecia or winter fruit-bodies of the hop-mildew fungus have been found to reach maturity in March and have been shown to be capable of causing infection in the greenhouse at that time of the year.

3. In artificial inoculation experiments, the time elapsing between the sowing of spores of hop mildew on hop leaves and the appearance of a fair-sized mildew spot was found to be about ten days.

4. It has been observed, also, that fresh mildew spots appear in approximately ten days after each rain. This leads to the inference that infection occurs during periods of wet weather, and indicates the advisability of applying sulphur as soon as possible after such periods in order to destroy the developing colonies of mildew.

5. During the past three years there have been made a considerable number of experiments in which flowers of sulphur, heavy flour sulphur and fine flour sulphur have been compared with respect to their efficiency in the control of hop mildew. In 1912 and 1913, control with all three kinds of sulphur was so nearly perfect that little difference could be detected even though the loss from mildew on the untreated plats ranged from 50 to 100 per ct. In 1914, conditions were generally more unfavorable for sulphuring and the tests of different kinds of sulphur therefore more severe. Under these conditions the average percentage of hops free from mildew on the unsulphured portions of six yards was only 5, while on the treated portions it was 78. The percentage of hops so badly mildewed as to be worthless on the unsulphured portions of the six yards was 61 while on the sulphured portions it was only 5.

The average percentage of hops free from mildew on the portions of these yards treated with flowers of sulphur was 68, on the portions treated with heavy flour sulphur 82 and with fine flour sulphur 83.

6. Flowers of sulphur has been found to be very variable in mechanical condition. Some it was impossible to apply satisfactorily. This sulphur in poor condition has been found to contain considerable amounts of sulphuric acid, which appears to be the cause of the trouble. Extremely fine flour sulphur has proven rather difficult to sieve and apply. Flour sulphur of a medium degree of fineness seems to be equally efficient, easier to handle, and cheaper. Coarse flour sulphur containing little or no fine sulphur is to be avoided.

7. Practical control has been successfully accomplished on a large scale by hop growers' cooperative associations. About seventeen hundred acres of hops have been included in such work within the last three years. The average amount of sulphur used per acre for the season has been approximately 190 pounds. There has been a large variation in the amount necessary to secure control in individual yards and also in the same yards in different years. The average for the Waterville association in 1912 was 165 pounds of sulphur per acre, in 1913, 160 pounds, and in 1914, 249 pounds. The average expense of sulphuring has been about eight dollars per acre per season.

INTRODUCTION.

CONTINUED IMPORTANCE OF THE DISEASE.

The appearance of the hop mildew (*Sphaerotheca humuli*) in a few hop yards in 1909 has been followed each year by reports of damage done in new districts, until, in 1912, no hop growing district in New York State seemed to have been missed although these districts are rather widely separated. It was first reported in Waterville in 1909;[1] in 1910, it was quite serious also at Middleburg; in 1911, it became serious in the Milford valley and about Cooperstown; and in 1912 it did serious damage about Malone in the extreme northern part of the State and in the hop-growing section about Canandaigua lake, both comparatively isolated districts. During 1913, badly mildewed leaves and hops were received from a hop

[1] An account of the early history of hop mildew in New York is given by Stewart and Whetzel on p. 356 of Bulletin 328 of this Station.

grower in Fournier, Ontario, Canada, who had lost about four tons of hops. The disease was noticed in that section for the first time about July 27 of the same year.

The damage by mildew was probably greatest in 1912. During that year the losses in New York State could scarcely have been less than one-third million dollars. In 1913 conditions were much better, yet heavy losses occurred in some districts where little sulphuring had been done. Although the year 1914 proved to be one in which the mildew was difficult to combat, the writer believes that the average losses due to mildew were little if any greater than in the year previous. In fact, in some sections, the control was decidedly better, due to the extension of sulphuring operations. That such an extension actually occurred is evidenced by the fact that more than eighty new dusting machines were put in operation and about one-half more sulphur was used in the State than during the year previous.

INJURY BY HOP APHID IN 1914.

Unfortunately, the latter part of the season of 1914 proved favorable also for the hop aphid. Early in the season this insect seemed comparatively scarce in most yards, but late in July and throughout August, its numbers increased rapidly. At this time the hops were formed and the aphids in many cases had penetrated between the bracts, so that it seems doubtful whether effective spraying could have been done after the conditions had become at all alarming. Once inside the hops, the aphids continued to increase up to picking time, producing the usual honey-dew, accompanied by a black mold. This mold and honey-dew seriously affected the appearance of the hops and where the aphid attack came early the hops were much dwarfed. Thus, the aphid contributed to make the 1914 crop of hops for New York, the poorest for several years.

SCOPE OF THIS WORK.

The work reported in this bulletin is a continuation of investigations and experiments conducted under the direction of Cornell University Station from 1910 to 1912 and published in Bulletin No. 328 of that station. It has seemed desirable to continue the testing of control measures in order to learn under what conditions they will prove effective and whether they may be relied upon under the

different weather conditions always experienced in a period of several years. At the same time, some studies and observations have been made on certain phases of the life history of the mildew fungus, which, it is believed, have an important bearing on the method of control. Practical control measures have been carried out on a large scale by hop-growers in cooperative associations. Statistics of this work are thought to be valuable as a measure of the practicability of these control methods. These things are here considered because it is believed that they will contribute to a better understanding of the disease and its control.

OBSERVATIONS ON LIFE HISTORY OF THE FUNGUS.

MATURATION AND DEHISCENCE OF THE PERITHECIA.

Salmon [2] has described the dehiscence of the perithecia of this fungus. He gathered hop leaves bearing perithecia in January and found that, after they had been kept three or four months in the dry condition, they would dehisce if placed in water. The writer has found, on the contrary, that perithecia on leaves and hops collected during the springs of 1913 and 1914 were in condition to dehisce at once without being kept under dry conditions. When collected early in the winter they dehisced better if kept out of doors under as nearly natural conditions as possible. Parts of vines bearing mildewed hops and leaves were collected in two localities on April 4, 1913. Most of these were taken from vines that had been stripped from the poles and lay in piles on the ground over winter. When brought into the laboratory on April 6, perithecia from both lots were found to be in a condition to dehisce at once; and when last tried, on May 21, they were still capable of dehiscing.

During the winter of 1913–14 several lots of perithecia were secured that were capable of dehiscence. One lot, collected about the middle of November from hops grown in the greenhouse, was placed out of doors in a protected place. Another collected near Index on December 10 from a yard ruined by mildew, was divided into two parts, one of which was placed out of doors, and the other kept in the laboratory. Trials made early in December with perithecia from the hops taken from the greenhouse and placed out of

[2] Salmon, E. S. Notes on hop mildew (*Sphaerotheca Humili* (DC.) Burr.). *Jour. Agr. Sci.* 2:327–332. 1907.

doors in November indicated that some were nearly ready to dehisce. That is, the perithecial wall burst in a number of cases and the ascus inside swelled to the dimensions usually attained before the expulsion of spores. However, dehiscence did not actually take place in any observed instance. Leaves of the same lot bearing perithecia were brought into the laboratory on January 20. At this time, within ten minutes after placing in water, many perithecia were found with their walls split at the apex and the asci swollen to the size of the original perithecia. From a few the spores had been discharged at the end of thirty minutes.

Of the hops collected at Index on December 10 and placed out of doors at Ithaca, some were brought in on February 20, but the perithecia did not seem ready to dehisce immediately. When they were placed on moist blotting paper in a petri dish, dehiscence took place in the course of three days, and spores were found on a slide suspended above them. Others brought in on March 24 and treated similarly were found to have dehisced on the 26th and in some instances the ascospores had germinated and the germ tube had grown to two or three times the length of the spore. Dehiscence took place more rapidly in the case of perithecia from hops left out of doors until April 14.

Another lot of leaves and hops bearing perithecia was collected from the same field at Index on March 27, 1914. These dehisced readily on being brought to the laboratory and placed in water.

Frequent trials were made during the two years with perithecia from leaves and hops brought into the laboratory and left several weeks in the dry condition. No improvement in the dehiscence was ever noticed from this treatment. Perithecia which were not capable of dehiscing when brought into the laboratory did not become so later by being kept in a dry condition.

These observations seem to indicate that perithecia are mature and ready to discharge the spores which cause infection as soon as the weather is sufficiently warm and moist.

The manner of dehiscence of perithecia has been repeatedly observed by the author. Within a few minutes after being placed in water, the perithecia begin to split at the apex. The tip of the ascus immediately slips out through this slit pushing it wider open. The ascus continues to swell, though apparently restrained by the friction of the walls of the perithecium, until sufficient pressure is

developed to enable it to slip farther out, usually with a rather sudden movement. However, the basal end of the ascus remains within the perithecium throughout the process of dehiscence as described by Salmon. Frequently, the splitting of the perithecium and the swelling of the ascus to near the bursting point occupies only a few minutes. Usually a longer period, sometimes a half hour or more, then elapses before sufficient tension is developed to effect the rupturing of the tip of the ascus. The spores are then suddenly shot out and the ascus collapses, allowing the perithecium to close partially.

In April, 1913, a few tests were made to determine the height to which spores are shot. Pieces of old leaves and hops were placed in the bottom of a moist chamber with slides supported above them. In one case where a slide was placed so as to be 5 millimeters above the perithecia at one end and 9 millimeters at the other, spores were caught throughout its length. In another case they were caught on a slide 1 centimeter above the perithecia, but much more abundantly on another slide at a height of 5 millimeters. Frequent cases were recorded where the spores were shot to a height of 5 millimeters.

INOCULATION EXPERIMENTS WITH ASCOSPORES.

The inoculation experiments here recorded were made on hop plants in a greenhouse at Ithaca. In the spring of 1913 two series of inoculations were made — one with ascospores caught on glass slides placed above perithecia, the other with the perithecia themselves. Two others, with perithecia, were made in the spring of 1914. In all four series of inoculations both the inoculated plants and the check plants were covered with bell jars for about 36 hours after inoculation. No mildew occurred on any of the check plants and there was no mildew on any hop plants in the greenhouse previous to the time of the first inoculation in either year. The perithecia used for inoculation were taken from hop leaves over-wintered out of doors. Spots became visible on inoculated leaves in 7 or 8 days in each case. At the end of 10 days or 2 weeks, the spots had increased in size so as to be easily seen at some distance and were comparable in size with spots easily discoverable in the field. Such a spot 10 days old as seen through a microscope is shown in Plate I, fig. 1. The mycelium showing faintly may be seen spreading in

FIG. 1.—HOP MILDEW SPOT TEN DAYS OLD.
(Magnified 50 times.)

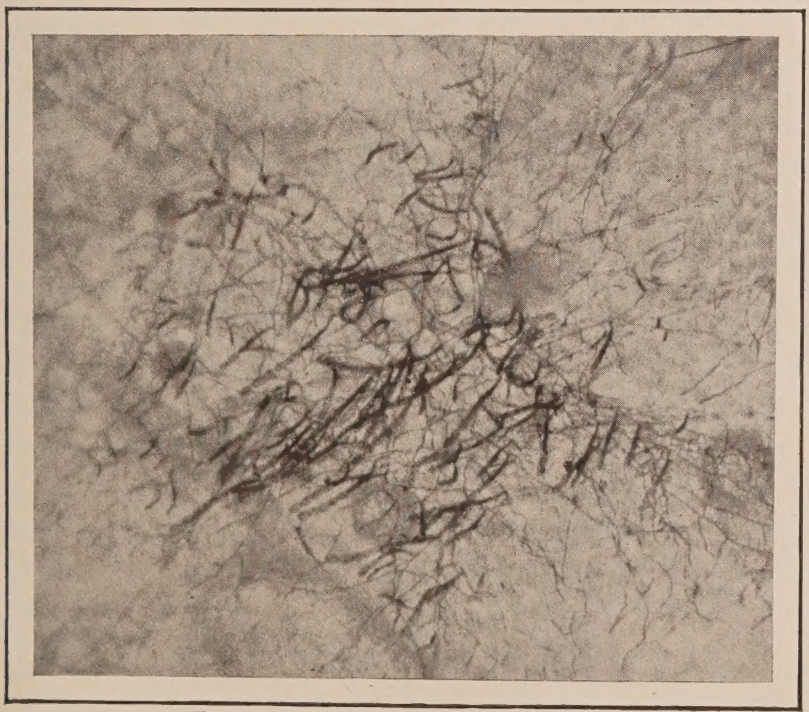

FIG. 2.—HOP MILDEW SPOT TEN DAYS OLD.
(Magnified 95 times.)

PLATE I.

all directions from a common center. In the center of the spot could sometimes be discovered the ascospore from which the spot started with four or five mycelial strands running out from it. The mature conidiophores may be seen in Plate I, fig. 2 in the center of the spot with a gradation to the youngest beginnings of conidiophores toward the periphery of the spot. The branching mycelium extends far beyond the point where conidiophore formation has begun. Earlier examinations of leaves, inoculated at the same time, showed that at the end of three days conidial formation had not yet begun in most instances, but that the spot consisted of fine mycelial filaments spreading and branching in every direction from the original ascospore. At the end of six days, the mycelium had spread and branched more extensively and usually a few (5 to 10) conidiophores had been formed in the center. The formation of conidiophores is the principal factor in making the mildew spots apparent to the eye.

HOP MILDEW AND STRAWBERRY MILDEW.

An interesting observation was made during the early part of the season of 1914. On a hop farm near Cooperstown, part of the yards had been plowed up two or three years previously and on about an acre of this land strawberries had been set in 1913. At the same time, as is usual, many of the old hop roots had not been entirely removed, so that living hop plants were scattered through the yard among the strawberries. On June 12 the writer's attention was directed to this bed of strawberries which at that time appeared severely affected with powdery mildew. Search was then made of the bearing hop yards remaining on the place and also of the vines intimately entangled with the strawberries without finding any mildew yet on the hops. The fact that the strawberries were so thoroughly infested with mildew when none could be found on the hops interwoven with them indicates that the mildew on the strawberry is a different biologic form of *Sphaerotheca humuli* from that on the hop. This is in accord with the view, now generally accepted, that the hop mildew is a specialized biologic form which is confined to the hop and its near relative, *Humulus japonicus*.[3]

[3] Salmon, E. S. On the specialization of parasitism in the Erysiphaceae II. *New Phytol.* 3:118–121. 1904.
Salmon, E. S. Notes on the hop mildew (*Sphaerotheca Humuli* (DC.) Burr). *Jour. Agr. Sci.* 2:330–332. 1907.
Steiner, J. A. Die Spezialisation der Alchimillen-bewohnenden *Sphaerotheca Humuli* (DC.) Burr. *Centbl. Bakt.* [etc.] 2:21:677–736. 1908.

RELATION OF SPREAD OF MILDEW TO WEATHER.

REVIEW OF LITERATURE.

In the early history of this disease, as probably with most others, many and varied were the attempts to ascribe it to some kind of weather. This proved easy enough for one year at a time, but in the course of time, as seasons varied, it has been charged against nearly all possible kinds of weather. To quote a few of these, Rutley [4] says, "The mold is most prevalent in moist and warm summers." Paine [5] writes, "We believe it to be a parasitical vegetable fungus, usually generated in wet seasons and damp situations." Whitehead [6] in various papers has offered theories and observations. In 1881 he states, "It is commonly believed that the hop plant is predisposed, by an unhealthy and abnormal condition, to be affected by mildew or mould; . . . A sudden check, caused by spring frosts or cold weather, may bring about this predisposition." In a later paper (1887) he writes, "In 1860, the wettest summer of the present century, the entire crop upon thousands of acres was utterly ruined by it. In this last summer, one of the most dry of this century, many hop grounds yielded nothing on account of its attacks upon the cones." In 1910, Percival [7] writes, "If the nights are cold and damp and the hop plants in a backward or weakened condition, the patches soon increase in size." In another place in this article he seems willing to attribute the attacks of mildew to nearly any kind of weather; he says, "Anything which reduces the vitality of the hop — such as cold damp nights, long continued drought, or wet weather and lack of proper sunshine and fresh air – indirectly aids mold in its ravages." Salmon [8] speaking of *Sphaerotheca humuli* occurring on strawberry writes, "As regards the climatic conditions favorable to the disease, there seems to be a consensus of opinion among gardeners that these are to be found in

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[4] Rutley, Samuel. On the best mode of managing hops in its various branches. *Jour. Roy. Agr. Soc.* 9:532–582. 1848.

[5] Paine, J. M. Hop. A Cyclopedia of Agriculture, London (Blackie and Son), p. 57. 1856.

[6] Whitehead, Chas. Hops. p. 55. 1881.

Whitehead, Chas. The hop mildew or "mould." *Podosphaera castagnei* Lév Ann. Rpt. Great Britain Agr. Advisor 1887:33–42.

[7] Percival, John. Hop mildew. Agricultural Botany, Theoretical and Practical. pp. 749–756. 1910.

[8] Salmon, E. S. The strawberry mildew (*Sphaerotheca Humuli* (DC.) Burr.). *Jour. Roy. Hort. Soc.* (London) 25:132–138. 1900–1901.

sudden alterations of temperature, especially in a decrease of temperature during the night, or a cooler temperature followed by hot weather." He also found that conidia germinated better after being cooled for a time. According to Norton [9] the spread of rose mildew is favored in the greenhouse by drafts of cool air coming in at ventilators, crevices, broken glass, etc. Bondarzew [10] concludes from germination and inoculation experiments with conidia of *S. humuli* on hop in May, when the temperature was low and the weather moist, and in June, when the temperature was high (20–25° C.) and weather moist, that warm, moist weather is favorable for the development of this fungus. Ward [11] in 1901 has expressed a similar opinion in regard to wet weather: "It is only in certain seasons, when the air is damp for some time, that these conidial segments are developed in any quantity, but when such is the case they are so numerous, and so easily carried from plant to plant, that no wonder need be expressed at the rapid spread of the disease; moreover it is in just such seasons that the hop leaves and 'cones' are particularly tender and watery, their cell walls thin, and their recuperative power low, whence we have other important factors favourable to the spread of the fungus. Finally, it is in such wet surroundings that the conidia meet with the best conditions for rapid germination."

OBSERVATIONS FROM 1912 TO 1914.

The writer has pointed out in a previous bulletin [12] that the appearance of new mildew spots on the hop seems to follow ten days or two weeks after the rainy periods. This conclusion was arrived at from two series of observations, one made at Waterville and the other at Milford during the year 1912. Similar records have now been made for the years 1913 and 1914 for two places in the hop-growing section of the State. These are charted in Figure 1 to show time and amount of rainfall and times of appearance of principal infections. The records at Cooperstown were made by the author; the others, by men engaged in inspection work for the hop growers' associations at Waterville and Milford.

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[9] Norton, J. B. S. Rose mildew. Maryland Sta. Bul. 156:76–78. 1911.

[10] Bondarzew, A. S. (In Russian.) The powdery mildew disease of hops and control experiments in a hop yard of Miskovsky of the Kostroma district. *Jahrb. Pflanzenkr.* (St. Petersburg) 2:16–28. 1908.

[11] Ward, H. M. The hop disease. Diseases of Plants pp. 153–155. 1901.

[12] Blodgett, F. M. Hop mildew. New York Cornell Sta. Bul. 328:290–291. 1913.

In Fig. 1, heavy horizontal lines separate observations for different places and for different years in the same place. Beginning at the top, there appears, above the first line, the record of rainfall and appearance of new mildew infections for Waterville in 1912, then below in order, Milford in 1912, Waterville in 1913, Cooperstown in 1913, Cooperstown in 1914 and Waterville in 1914.

The spaces between the light vertical lines represent periods of time of one day each. The heavy vertical lines divide the time into ten-day periods. The amount of rainfall occurring on each day is indicated by the height of the black areas; the distance to the first light line in each case representing a half inch and to the second line one inch. Rainfall not measured, but estimated, is represented by an outlined area containing an X. Mildew infections are represented by outlined areas.

By reference to the part of the chart representing Waterville for 1912, it will be seen that the first mildew infections were found appearing in a few yards on June 18 and 19, probably having started during a rain occurring on June 6. Many light infections were found in yards from the third to the sixth of July which seem to have started in the showers of June 20 and 21. Heavier infections appearing on July 15 and 20 appear to have started on July 4 and 9 respectively. For the remainder of the season, rains occurred more frequently and infections came closer together until, during the last of August and early September, it became quite impossible to distinguish between individual infections. During the latter part of the season observations were made in new yards. In general, it may be said of the season of 1912 at Waterville, that only a few mildew spots could be found till about the middle of July. At this time there seemed comparatively little danger to the crop from mildew. During the last of July and during August, however, the rate of increase was so rapid that many yards not sulphured, or sulphured little, were lost.

At Milford in 1912, the conditions were very similar. A few slight infections were observed on June 10. No record is available of the weather conditions previous to June 7, so during what rain this started is not known. Further infections appeared from June 18 to 20 as at Waterville, having started in the rain on June 6. A light shower on June 12 (which did not occur at Waterville) gave rise to mildew on the 25th. No observations were made during the

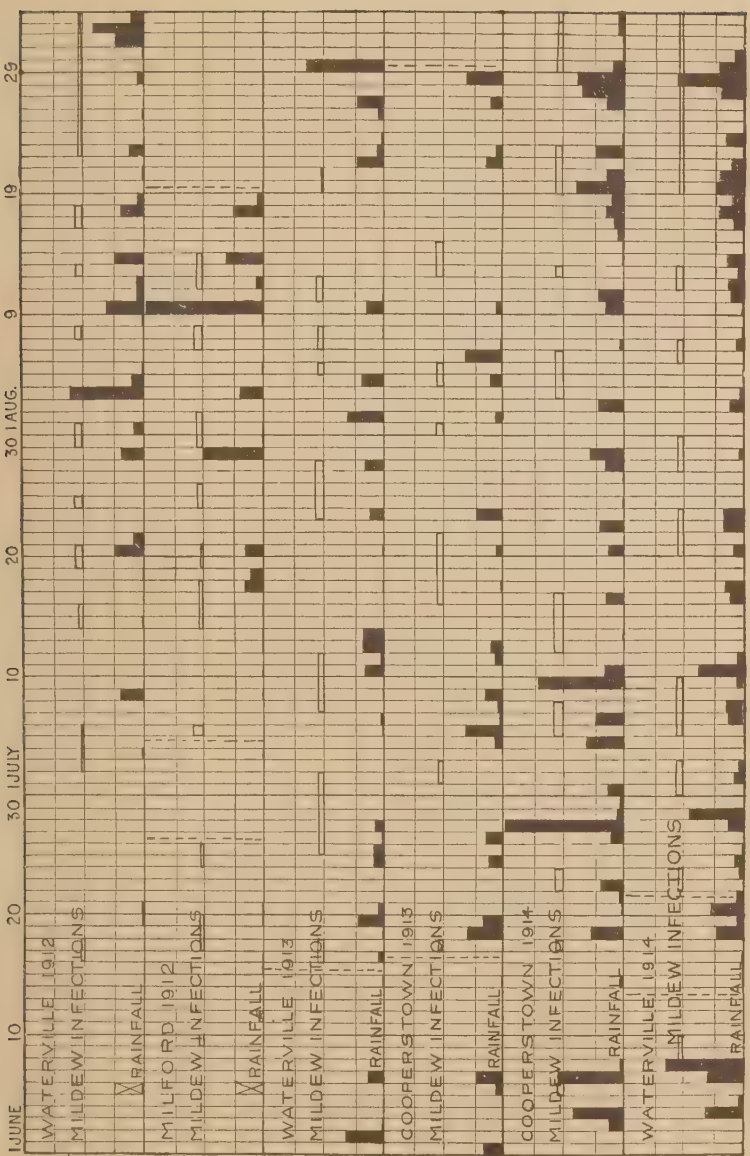

Fig. 1.— Chart Showing Relation of Rainfall to Development of Mildew Spots.

period from June 27 to July 5 inclusive. New mildew spots were observed in many places on July 6. These would probably have been discovered earlier, as at Waterville, had observations been made. Throughout the remainder of the season, the rains occurred frequently, as at Waterville, followed quite regularly by the appearance of mildew in ten days. The principal variation from the condition at Waterville was the occurrence of a larger number of early infections.

In 1913, a visit was made to Waterville about June 1st when no mildew was found. No further observations were made until June 17. It is not known, therefore, whether any infection might have been found previous to the 17th. The mildew found on that date seemed to be comparatively fresh and could probably be attributed to the rain on the seventh of June. Light showers on the 15th followed by a week of showery weather gave rise to new infections of mildew which appeared from June 24 to July 1. Rains June 25 to 28 were followed by the appearance of mildew from July 8 to 12. Following this there appeared many very slight infections (July 18 and 19) probably traceable to the showers of July 6 and 7. Heavier infections were reported in a few cases from the 24th to 28th following the rains of July 11 and 14. No record was made in 1913 of the infections in the new yards after the hops had been picked in the bearing yards.

At Cooperstown, in 1913, no record of mildew infections was begun until June 17 though mildew had been found in quantity in an abandoned yard on the third of June. When observations were begun again on June 17, fresh mildew spots could be found in a number of yards, probably having started in the rains of June 6 and 7 as at Waterville. Rains occurred in Cooperstown on June 19 and 20 and there was some evidence of light infections on July 2 and 3 though comparatively few observations were made at that time. Rains on July 5 to 9 gave rise to infections which began to appear on July 17. Rains on July 21 and 24 were followed by infections on July 31 and August 5. A very general infection which began to appear on August 13 originated in rains beginning August 2.

At Cooperstown in 1914, the rains were more frequent and heavier so that it soon became difficult to distinguish between different infections. Accordingly, the chart shows only periods of heaviest and most general infection. The first infections recorded on June 6 apparently began at an earlier date than any rain shown on the chart

and before any weather record had been begun. No further infections were recorded until June 18. These clearly started in the rains on June 7 and 8. A new, light, but more widely spread infection, appeared on June 23 and 24, having started in showers on June 15. A rain on June 19 would have led one to expect mildew about June 29, but as this was a very rainy period no observations were made. Heavy infections resulting from rains in the last days of June were reported from July 6 to 8. Observations were again interrupted by rains, but heavy infections were again reported on July 13 and heavier ones three and four days later. On the last two days mentioned the spots appeared extraordinarily healthy. New spots were not only numerous but the production of spores on all spots was heavy.

Some new infections of mildew might have been expected about the tenth of August, or soon after this, but there was an interruption in observations from the eighth to tenth and rains on the tenth and eleventh and beginning again on the fourteenth caused a further interruption. Some indications of such an infection were noted on the thirteenth in limited observations. More decided increases in mildew began to appear about August 20. Following this, increasing amounts of mildew could be found on hops till picking time and thereafter on the plants in the new yards till the middle of September.

No rainfall record was made at Waterville in 1914. The rainfall as shown on the chart is the average for the five Weather Bureau Stations nearest Waterville. For the most part rains occurred at these different places at the same time so that the dates of the general rainy periods at Waterville may at least be relied upon as given by the chart. From June 14 to 22 no observations were made, else the infections noted on June 23 and 24 might probably have been found sooner. Rains were frequent, as at Cooperstown, followed by correspondingly frequent mildew infections.

MILDEW INFECTION TAKES PLACE DURING RAINS.

Thus it appears that the new mildew spots begin to show about ten days after rainy periods. This, to the writer, seems to be the most important relation of the increase of mildew to weather conditions. In the effort to discover the relation of the weather to the spread and growth of the mildew, a daily record was made also of the maximum and minimum temperature and relative humidity.

It seems altogether probable that each of the other factors may have some effect on the growth of the mildew but their influence is not so apparent.

The field observations reported above seem to indicate that the spores of the mildew, like the spores of many other fungi, germinate and begin to grow during wet weather. The length of time between these wet periods and the appearance of new mildew spots corresponds well with that between the sowing of spores and the appearance of mildew in artificial infections.

This seems to be in accord with many of the statements previously referred to, namely, that the worst epidemics have occurred in wet seasons. At the same time, in comparatively dry seasons a few rains at critical times could easily account for heavy losses. The writer has frequently seen yards in which it was very difficult to find mildewed spots on the leaves, yet a heavy infection of the flowers or young hops nearly or quite ruined the crop.

The importance of a knowledge of this relation between rain and mildew infection seems to be that it affords the hop-grower a guide as to when he may expect new attacks of mildew on his hops. It should, therefore, be of assistance in its control. Clearly, it becomes important to sulphur after each rain unless the hops were well covered with sulphur before the rain and the rain not heavy enough to remove it.

OTHER CONDITIONS AFFECTING GROWTH OF MILDEW.

That there are other influences which affect the growth of the mildew is very apparent. Yards near enough together to be equally affected by periods of wet weather frequently show great differences in severity of mildew attacks though new spots may appear in both at the same time. Different varieties and even different leaves on the same plant vary in susceptibility. Named in order of susceptibility beginning with the most susceptible, the New York varieties would be arranged as follows: Canada red vine, English cluster, Humphrey and native red vine. No serious injury has been noticed, so far, on the native red vine variety though planted near badly infested yards and, in some instances, scattered through yards of a susceptible variety. It is said to be a light yielder, however.

On individual vines the younger leaves or other growing parts are most susceptible to the mildew. Early in the season the mildew may be expected on any of the leaves of the plant, but after the leaves near the base have developed to their full size though still green and healthy, new infections are much rarer on them than on leaves of young arms or near the tips of the vines. The flowers and young catkins (" cones " or " burs ") are especially susceptible.

It may be said, also, that the spots seem to enlarge most rapidly, look most healthy and sporulate most abundantly at a time when conditions are such as to cause a rapid development of the host plant, i. e., in warm, moist weather. In 1914, such a period was noticed about July 16. Frequent, heavy rains between the last of June and the tenth of July were followed by five or six days of comparatively warm weather. On the sixteenth, then, the mildew spots appeared particularly healthy. The conidiophores, which in continued dry weather are few and scattered, were now numerous and producing conidia in abundance. Indeed, the spores were so abundant that they could be shaken from the leaves in clouds.

Similar conditions have also been observed earlier in the season, in places where the mildew obtained an early start. In such cases, the mildew has frequently been found completely covering young leaves, petioles and tender stems. Later in the season, when the leaves have more nearly reached their full development, the mildew is usually confined to circular spots on the leaves which frequently do not reach the size of one centimeter in diameter.

Of some interest in this connection are the observations recorded by Halsted [13] and by Anderson and Kelsey.[14] In each case it was found that the powdery mildew developed more luxuriantly on parts of plants that had been stimulated by mites to form distortions. Halsted found perithecia of Sphaerotheca abundant in the buds of hackberry which had been affected by mites. Anderson and Kelsey found the mildew and mites together on a number of plants and concluded that in every case where these forms of animal and vegetable life are so associated, there is a more vigorous development and earlier maturity of the fungus than under ordinary cir-

[13] Halsted, B. D. Notes on *Sphaerotheca Phytoptophila*, Kell. and Swingle. *Jour. Mycol.* 5:85–86. 1889.

[14] Anderson, F. W., and Kelsey, F. D. Erysipheæ upon Phytoptus distortions *Jour. Mycol.* 5:209–210. 1889.

cumstances. This seems to be in accord with what has previously been said about the growth of the fungus on the younger and more tender parts of vines. During the summer of 1914, it happened that a woodchuck ate off the vines in one corner of a yard after they were well started up the poles, with the result that these vines started many new shoots which were more tender and less mature than the vines in the other parts of the yard. The further result was that these vines were soon covered with mildew though treated in the same way as the rest of the yard which was but slightly affected.

On the other hand, it has been observed several times in abandoned yards where mildew has attacked the plants particularly early and been allowed to go uncontrolled, that as the growth of the hops became checked because of lack of cultivation and the presence of grass and weeds, the mildew spots, also, stopped spreading on the leaves and the mildew no longer looked healthy.

Thus it appears that there are some factors in the condition of the hop plant which greatly affect the rate of development of mildew. Favorable conditions seem to be found principally in the younger growing parts of plants but in what these conditions consist has not been determined.

USE OF SULPHUR IN THE CONTROL OF MILDEW.

HISTORICAL.

Sulphur has long been used for the control of various powdery mildews, more particularly those of the grape and hop. Stevens and Hall[15] attribute the discovery of the use of sulphur for this purpose to Robinson in 1821 who is quoted as stating, "Sulphur is the only specific remedy that can be named for the treatment of mildew on peaches. It should be mixed with soapsuds and then applied by dashing it violently against the trees by means of a rose syringe." It did not come into general use until after 1850 or until the powdery mildew became a scourge to the grape vines of Europe. It was apparently then rediscovered by Tucker[16] who is quoted as having first used a mixture of sulphur and lime for the control of

[15] Stevens, F. H., and Hall, J. G. Diseases of economic plants. p. 7. 1910.

[16] Tucker, E. Letter of E. Tucker to Gaschet. Documents pour servir à l'étude de la Maladie de la Vigne. pp. 12–14. Pub. by the Linnéenne society of Bordeaux. 1853.

this disease in 1845. Reference to its use is made by a number of authors beginning with von Mohl[17] in 1852, Mares[18] in 1855 and others. The powdery mildew of grapes which did its maximum damage in France in 1854 was so speedily controlled that normal production was reached again in 1859.

It seems that comparatively little is known about the early use of sulphur on hops. Apparently its use on hops followed its successful use in the control of grape mildew, though the mildew had been present on the hop in England about a century and a half earlier than on the grape. An article, probably by Berkeley,[19] in 1869 seems to assume that sulphur would be as effective against the mildew on the hop as on the grape. Whitehead[20] wrote that sulphur had been of great use to the hop growers for the 25 years previous. At the time of his writing the practice of sulphuring hops was well established.

Mixtures of flowers of sulphur and lime were early recommended but seem to have been used comparatively little, though such recommendations may be found in the recent as well as in the older literature.[21]

Flowers of sulphur was first used because it was the only kind of fine sulphur then manufactured, but, later, the grinding of sulphur was much perfected and flour sulphur to a considerable extent has replaced the flowers of sulphur in some countries of Europe.

In the meantime, the question of how sulphur acts has been attacked and various theories have been made the basis of recommendations. It is not the writer's purpose in this bulletin to review all of the work or opinions on this subject. The earlier work has been reviewed by Sestini and Mori,[22] Windisch [23] and other writers.

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[17] Mohl, Hugo von. Die Traubenkrankheit. *Bot. Ztg.* **10**:9–15. 1852.

[18] Mares, M. Sur la maniere dont la fleur de soufre agit contre le maladie de la vigne. *Compt. Rend. Acad. Sci.* (Paris) 2:41:397–399. 1855.

[19] B[erkeley], M. J. Hop. In a Cyclopedia of agriculture, by Morton. 2: 66–67. 1869.

[20] Whitehead, Chas. Hops. pp. 55–58. 1881.

[21] Tucker, E. 1853 l. c.
Ward, H. M. Diseases of plants. p. 161. 1901.
Galloway, B. T. Powdery mildew of the bean. *Jour. Mycol.* **5**:214. 1889.
Duggar, B. M. Fungous diseases of plants. p. 90. 1909.
Lodeman, E. G. The Spraying of plants. pp. 174–176, 307. 1906.

[22] Sestini, F., and Mori, A. In qual modo opera lo zolfo sull'oidio della viti. *Staz. Sper. Agr. Ital.* 19:257–278. 1890.

[23] Windisch, Karl. Ueber die Wirkungsweise, Untersuchung und Beschaffenheit des zur Bekämpfung des Oidiums dienenden Schwefels. *Landw. Jahrb.* 30:447–495. 1901.

It has been shown, principally by Moritz,[24] Basarow,[25] Mach and Portele[26] and Sestini and Mori,[27] that there is a certain amount of sulphurous acid formed in a sulphured vineyard and it has been quite generally accepted that this is an active agent in killing the mildew. Sestini and Mori also showed that the sulphurous acid formed is changed, in part at least, into sulphuric acid. Pollacci[28] has shown some of the conditions under which the oxidation of sulfur takes place and agrees that the end product is sulphuric acid.

In this connection should also be mentioned the work of Kramer[29] who performed an experiment in which sulphur was heated to a moderate temperature as in the use of this material in the greenhouse, and found that the principal product was sulphuric acid. He believed that the efficiency of sulphur as used in the greenhouse is due to this acid and he found that dilute solutions of sulphuric acid are capable of killing the mildew. Marcille[30] has gone even farther and claims, on the basis of a few inadequate experiments, that the effectiveness of sulphur as used in dusting grapes out of doors is due to the sulphuric acid which it contains. He seems to believe that most of this is developed in the process of manufacture and very slowly afterward. On this basis he suggests that only flowers of sulphur should be used and that this should be manufactured to contain more sulphuric acid or that some less expensive carrier should be found for the acid.

That there is a certain amount of sulphur vapor formed from sulphur at ordinary temperatures is well known and that this may have some effect on fungus parasites has been recognized by many writers.

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[24] Moritz, J. Ueber die Wirkungsweise des Schwefelns als Mittel gegen den Traubenpilz (Oidium Tuckeri). *Landw. Vers. Stat.* **25**:1–4. 1880.

[25] Basarow, A. *Weinlaube* **14**:529. 1882. Cited in *Landw. Jahrb.* 30:151. 1901.

[26] Mach, E., and Portele, K. Zur Frage ueber die Art und Weise, in welcher der zur Bekämpfung des Oidiums angewendete Schwefel wirkt. *Weinlaube* **16**:433, 265. 1884.

[27] Sestini, F. and Mori, A. l. c. 1890.

[28] Pollacci, E. Ossidazione spontaneae del solfo e dei solfuri mettalloidici e metallici. *Monit. Sci.* 4:32:372–375. 1908. Same. *Atti. Cong. Chim.* (Roma) 1:482–488. 1907.

[29] Kramer, H. Dilute sulphuric acid as a fungicide. *Proc. Amer. Phil. Soc.* **45**:157–163. 1906.

[30] Marcille, R. Sur le mode d'action du soufre utilsés pour combattre l'oidium *Compt. Rend. Acad. Sci.* (Paris). **152**:780–783. 1911.

Mach and Portele not only considered how sulphur acts but which kind is most effective. They tried to solve this problem by determining the amount of sulphurous acid formed with different kinds of sulphur under the same conditions. They found in a limited number of experiments that a larger amount of sulphurous acid was formed from the finer material. They also found that the amount of sulphurous acid increased with an increase of temperature. The numerous published recommendations, which for the most part favor the use of flour sulphur, seem to be based in part on these experiments, but very largely, also, on other considerations, as follows:

(1) Flowers of sulphur has been largely replaced by ground sulphur in use in the vineyards of Europe. At first flowers of sulphur was exclusively used for the reason that ground or flour sulphur was not then made. Since ground sulphur as fine or finer than flowers of sulphur has been on the market, it has grown in popularity with the vineyardists until it has superseded the flowers of sulphur to a considerable extent.

(2) Ground sulphur may be made finer than flowers of sulphur if sufficient care is used in the grinding. The finer sulphur should be more active because the rate of oxidation and of vaporization depends in part on the area of surface exposed. This would be larger per unit weight for the smaller particles, and for the irregular particles of flour sulphur as compared with the spherical particles of flowers of sulphur of the same size. The small quantities of sulphurous and sulphuric acids always contained in flowers of sulphur should be rapidly balanced in favor of the finely ground sulphur by the more rapid oxidation of the latter. Fine sulphur may also be spread more evenly and widely.

(3) The particles of flowers of sulphur, being spherical or nearly so, will not cling as tenaciously to vine parts as do the irregular, sharp-cornered particles of the flour sulphur.

(4) The process of manufacture of flour sulphur is such that a uniform product is readily obtained. The process is one of grinding which may be continued until the desired fineness is secured. To obtain a uniform quality of flowers of sulphur involves maintaining a large building used for a condensing chamber at a uniform temperature under the varying weather conditions throughout the year.

If the temperature is too high the particles fuse, thus altering the fineness of the product.

Further statements in literature seem to deal principally with observations or preferences. No data from field tests of different kinds of sulphur are available. Guillon [31] states that he undertook such tests but found them impracticable.

There still persists, however, in many general treatises, the statement that flowers of sulphur [32] may be used for the control of certain mildews; also, recommendations for the use of a mixture of lime and sulphur. In many cases no reference is made to any other kind of sulphur, to present practice in vine-growing countries or to recommendations of specialists in mildew control.

From what has been said, it is seen that there exist a considerable variety of recommendations which are rather puzzling when one is first confronted with them. Many recommendations found seem to be quite indifferent as to the kind of sulphur but consider more important the purity and the fineness as determined by the Chancel test.

FIELD EXPERIMENTS COMPARING DIFFERENT KINDS OF SULPHUR.

GENERAL PLAN.

When, quite suddenly, the mildew became a serious menace to the hop crop of New York State and it became desirable to know if sulphuring is a satisfactory means of control under the climatic conditions existing here, it was decided to try out flowers of sulphur, fine flour sulphur and heavy flour sulphur and a mixture of lime and sulphur under field conditions with the hope of finding out, if possible, which is the most effective and of how much importance, approximately, are the differences in fineness.

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[31] Guillon, J. M. Soufres et bouillies cupriques. *Rev. Vit.* **19**:651–655. 1903.

[32] Recommend the use of flowers of sulphur:
Mohl, Hugo von. Die Traubenkrankheit. *Bot. Ztg.* **10**:9–15. 1852.
Koeth, Dael v. Ueber Traubenkrankheit. *Ann. d. Oenologie* **2**:118–121. 1872.
Whitehead, Chas. Chap. 13. Hops. pp. 55–58. 1881.
Galloway, B. T. Powdery mildew of the bean. *Jour. Mycol.* **5**:214. 1889.
Dufour, J. L'oidium. *Chron. Agr. Vaud.* **8**:229–234. 1895.
Tubeuf, Karl von. Diseases of plants. pp. 170–171, 172, 177. 1897.
Masee, George. A text-book of plant diseases caused by cryptogamic parasites. pp. 95–97. 1899.
Salmon, E. S. Monograph of Erysiphaceae. *Mem. Torrey Bot. Club* **9**:60. 1900.
Duggar, B. M. Fungous diseases of plants. p. 90. 1909.
Stevens, F. L., and Hall, J. G. Diseases of economic plants. p. 20. 1910.

For this work a very good grade of flowers of sulphur was secured. This kind of sulphur is ordinarily packed in 155-pound barrels and is a bright, golden yellow in color. Flowers of sulphur is sometimes in poor mechanical condition. The cause of this will be discussed on page 69. Such sulphur does not feed through machines well. The flowers of sulphur used in these experiments, so far as could be judged from general condition and taste, never contained a considerable amount of acid and was in excellent mechanical condition.

The heavy flour sulphur or ground sulphur was the ordinary grade of refined flour sulphur packed in 250-pound barrels. In color it was a bright yellow but not as bright in color as flowers of sulphur. It was of such a fineness that about 75 per ct. would pass a 200-mesh sieve.

The fine flour sulphur or ground sulphur used was packed in 175-pound barrels. In color it was a whitish yellow. To the touch this sulphur was very smooth and floury with no noticeable roughness such as may be noticed in the ordinary flour sulphur and flowers of sulphur. It was of such a fineness that practically all of it would pass a 200-mesh sieve.

While it may be said, in general, that the finer sulphur is ground the less can be packed in a barrel, the amount packed in a barrel is not always an indication of fineness, as the barrels may not be full. So it happens that much sulphur on the market in 175-pound barrels is coarser than that mentioned above, the barrels not being full.

With the three kinds of sulphur as above described, it was hoped that if there is any considerable difference in effectiveness between sulphur of different degrees of fineness, this could be detected and that the experiments would indicate the relative value of ground sulphur and flowers of sulphur.

Our first experiments of this kind were made in 1912 in cooperation with twelve hop growers. The results have been reported in Cornell University Agricultural Experiment Station Bulletin 328. In all cases the control was so nearly perfect that no distinction could be made between the two kinds of sulphur used — fine flour sulphur and flowers of sulphur. During the past two summers a number of other trials have been made.

The general plan of these experiments has been to select yards badly mildewed the year previous and divide them into three or

four plats — one plat left untreated (usually on the windward side to avoid the drift of sulphur when treating the adjacent plats), one plat sulphured with flowers of sulphur, one with fine flour sulphur, and, in some cases, a fourth plat treated with heavy flour sulphur. The different kinds of sulphur were applied to the different plats on the same day and as nearly as possible in the same amounts. The sulphur used on each plat, at each application, was weighed and the amount recorded except in a few cases of cooperative experiments when it was impossible for the writer to be present. In such cases the record was kept in parts of barrels per application or barrels of each kind for the season. The amounts actually applied varied from the desired quantities for several reasons. The machines could be regulated only roughly. The different kinds of sulphur necessitated different adjustments of the feeding device in order to distribute the same amount of material.

The result of the different treatments was determined by two separate methods. A really satisfactory method seemed difficult to find. The total weight of the crop did not seem to be of any value as a measure of mildew control because mildewed hops, though of little value, or worthless nubs weigh nearly or quite as much as the healthy hops. Sorting the hops into grades containing those affected and those not affected by mildew would be practically an endless task on any considerable area. Four or five thousand is not a large number of hops for a single hill. During the season of 1914, the following method was employed. To get samples, a trip was made through each plat, lengthwise, near its center, and small branches were removed from each vine without distinction, if such a branch were available. This seemed to furnish a satisfactorily representative sample of the different yards and the different parts of the yards. These samples were sorted into three classes, those free from mildew, those slightly mildewed but marketable, and those so severely mildewed as to be unmarketable or valueless. The hops in each lot were counted.

Considerable reliance has also been placed on an inspection of the yard shortly before picking. Slight mildew injuries to hops are almost at once apparent in the color and appearance of the hops before picking, much more so than in hops after they have been dried. It was therefore thought proper to place confidence to some extent in the judgment of dealers and growers who visited the

yards before picking, especially as it is customary to determine the quality of hops by inspection. As there is no uniform system of grading hops, or standards by which to compare any particular lot, except one part of the field with another or by a rough estimate of losses, such judgments have proven hard to record satisfactorily. It may be said that in 1913, as in 1912, it frequently happened that the control was so good on sulphured portions of the yards, that losses were quite imperceptible, while on untreated portions of the same yards the loss from mildew amounted to one-half or more of the crop. In 1914, however, with long and rather continuous rainy periods, there was little opportunity for sulphuring and at few times was the weather favorable for the action of sulphur. Under such circumstances the tests of the different kinds of sulphur were more severe. The yard was rare, indeed, that did not show enough injury from mildew to furnish a basis for judgment on the relative merits of the different kinds of sulphur. At the same time local variations in each yard played no small part in the results obtained, so that different hop-growers reached quite different conclusions in regard to the different kinds of sulphur being tested. It becomes at once apparent that a true conclusion in this case can only be based on the results of experiments in a considerable number of yards. The drift of clouds of sulphur while distributing quite excludes the possibility of dividing a hop-yard into numerous small plats to avoid this difficulty.

DETAILS OF EXPERIMENTS.

King farm, yard No. 3, 1914.— In 1913, this yard had been used for an experiment comparing a mixture of sulphur and lime with flowers of sulphur alone and it became badly mildewed. The year previous it had suffered a complete loss due to mildew. It is located near the top of Burke Hill, Index, N. Y., and is situated on the slope of the hill facing the west. It was divided so that a strip seven rows wide and twenty-seven hills long was left on the west side untreated. The adjoining plat, fifteen rows wide and forty-nine hills long was dusted with flowers of sulphur. The third plat, fifteen rows wide and forty-nine hills long, was dusted with an equal amount of fine flour sulphur.

The following table gives a record of the sulphuring of this yard:

TABLE I.—SULPHURING IN KING YARD NO. 3, 1914.

DATE.	SULPHUR PER ACRE.		Date of first rain following sulphuring.
	Flowers.	Fine flour.	
	Lbs.	*Lbs.*	
June 25	60	72	June 28 and 29.
July 22	73	71	July 23.
July 28	72	61	July 28 and 29.
August 4	72	58	Aug. 10 and 11.
Average	69	65.5	

Mildew was first observed in this yard on June 24. At that date a few spots were found scattered quite evenly about the yard. The applications of sulphur to this yard were followed closely by rains with the exception of the treatment on August 4, following which there was about a week of fair weather. No significant increase in mildew was noticed until July 13 and 17. This was checked somewhat by the treatments on July 22 and 28. The sulphuring on August 4 was undoubtedly the most effective as the weather was favorable and the hops were just growing out. The weather allowed no further opportunity for sulphuring.

During one of the storms this yard was severely damaged by hail so that a light yield resulted. Scattered hills in the yard were also injured by the hop aphid, but this injury was ignored in tabulating results.

Samples were collected on August 29 and classified as above described with the following results:

TABLE II.—CONDITION OF HOPS AT PICKING TIME IN KING YARD NO. 3, 1914.

PLAT.	Total number.	FREE FROM MILDEW.		SLIGHTLY MILDEWED.		VALUELESS.	
		Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
Unsulphured	1,601	.....	.....	68	4.25	1,533	95.75
Flowers	1,259	874	69.4	275	21.84	110	8.74
Fine flour	1,119	881	78.7	217	19.4	21	1.9

From this table it is apparent that the untreated portion of this yard was a complete loss — in strong contrast to both of the other portions of the yard. The plat sulphured with fine flour sulphur was better than that treated with flowers of sulphur as also appeared very clearly by inspection of the yard.

Wedderspoon yard.— This yard was chosen because it had been severely attacked by the mildew the year previous, so that only about half of the yard was picked; also, because it was one of the first in which the mildew was discovered in the spring of 1914. The yard is located in a narrow valley formed by one of the streams emptying into the west side of Otsego Lake in a locality known as Pierstown. It is situated on the southern side of the valley on sloping land, with the lower end of the yard only a little above the level of the stream.

Mildew was reported in this yard on June 6, 1914, and the report was verified a few days later by the writer although, at that time, most of the lower leaves had been removed by trimming in the hope of checking the spread of the mildew. No serious spread of the mildew was noted in this yard until June 23.

The yard was divided into plats running up and down the hill, with an untreated plat twelve hills square in the southwest corner. The following table gives a record of the sulphuring of this yard:

TABLE III.— SULPHURING IN WEDDERSPOON YARD, 1914.

DATE.	SULPHUR PER ACRE.			Date of first rain following sulphuring.
	Flowers.	Heavy flour.	Fine flour.	
	Lbs.	*Lbs.*	*Lbs.*	
June 24	51	69	56	June 28 and 29.
July 10	45	58	56	July 10.
July 16	63	64	52	July 17.
July 25	53	53	63.5	July 28.
August 7	83	62	62	August 10.
Average	59	61	58	

It is apparent that none of these applications was very happily placed, four days being the longest period following a sulphuring before a rain. The application of July 10 was the most unfortunate as a heavy rain in the afternoon washed off much of the sulphur applied in the morning.

As stated previously, an increase of mildew was noticed in this yard on June 23. This was more abundant in the part of the yard that was to be treated with flowers of sulphur. A further increase was noted on July 16 with a very heavy production of spores. The mildew continued considerably worse, up to picking time, in one end of the plat treated with flowers of sulphur. It should be remarked that this portion of the yard was also most severely affected the year previous. The unsulphured portion was on the other side of the yard and presumably the least likely to be affected.

Samples were collected from this yard on August 26 and sorted with the following results:

TABLE IV.— CONDITION OF HOPS AT PICKING TIME IN WEDDERSPOON YARD, 1914.

PLAT.	Total number.	FREE FROM MILDEW.		SLIGHTLY MILDEWED.		VALUELESS.	
		Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
Unsulphured	770	77	10.0	315	40.9	378	49.1
Flowers	1,105	899	81.4	176	15.9	30	2.7
Heavy flour	681	598	87.8	77	11.3	6	.9
Fine flour	702	626	89.2	71	10.1	5	.7

In this yard the unsulphured portion, while only a partial loss, still stood in marked contrast to the rest of the yard. There seems no doubt that had it been on the side of the yard treated with flowers of sulphur, the loss would have been total.

The table represents the observed condition of the yard very well. One end of the plat dusted with flowers of sulphur seemed equally good with the rest of the treated part of the yard, while the other end was considerably damaged.

Utter yard, Cherry Valley.— This yard was chosen because it

FREE FROM MILDEW. SLIGHTLY MILDEWED. VALUELESS.

PLATE II.—SAMPLES OF HOPS FROM EXPERIMENTAL PLATS IN WEDDERSPOON YARD.

Upper row, not sulphured; second row, flowers of sulphur; third row, heavy flour sulphur; bottom row, fine flour sulphur.

had been so severely attacked by the mildew the year previous that only a small part of the yard was picked. It was also one of the first yards attacked by the mildew in that section in the spring of 1914. The yard is located at a medium elevation and is nearly level, except at the eastern end, where one side runs up the side of a small knoll. In 1913, this end was more severely affected by mildew and in it the mildew was first found in 1914.

The yard, which was 88 rows long, was divided into plats running crosswise. These plats were about 30 hills square or contained about an acre each. This manner of division of the yard was found necessary because the spaces between the rows running lengthwise on one side were so narrow that the dusting machine could not be used in them. The plat at the western end was dusted with heavy flour sulphur, the plat in the middle with fine flour sulphur and the plat at the other end with flowers of sulphur. A check plat twelve hills square was located in the southwest corner of the yard. In this end of the yard containing the check and the part dusted with heavy flour sulphur the mildew was least abundant the year previous.

In 1914 mildew was found in this yard on June 19. An increase of mildew was noted on July 6. It is likely that these spots might have been seen several days earlier had observations been made. The shipment of sulphur was delayed and rains further deferred the application of sulphur until July 13. By this time considerable increase in the mildew had taken place, particularly in the eastern end of the yard. The following table gives a record of the sulphurings in this yard:

TABLE V.—SULPHURING IN UTTER YARD, 1914.

DATE.	SULPHUR PER ACRE.		
	Heavy flour.	Fine flour.	Flowers.
	Lbs.	*Lbs.*	*Lbs.*
July 13	55	54	54
July 25	80	49	77
July 31	66	51	60
August 13	75	47	87
August 25	.....	.....	.....
Average	69	48	69.5

The weather record at Cooperstown applies only approximately to the conditions in this yard. It is known that rains were quite as frequent here as elsewhere and that the treatments on July 25 and 31 were followed shortly by rains. That on August 13 fell within the period when showers were of daily occurrence. An application of sulphur was made by Mr. Utter on August 25 as nearly like the others as possible. This was done because Mr. Utter wished to delay picking for some time. It was thought to have had very little effect on the results recorded as it was followed almost immediately by heavy rains.

The machine used in this case was not entirely satisfactory as it proved to be very difficult to regulate. With the fine flour sulphur it was always wide open. From the table it may be seen that the amount of fine flour sulphur used averaged 20 pounds less per application than for either of the other kinds.

Samples from each of the different plats of this yard were collected on September 2 and examined as usual with the results shown in the following table:

TABLE VI.—CONDITION OF HOPS AT PICKING TIME IN UTTER YARD, 1914.

PLAT.	Total number.	FREE FROM MILDEW.		SLIGHTLY MILDEWED.		VALUELESS.	
		Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
Unsulphured	1,567	62	3.9	587	37.5	918	58.6
Flowers	1,197	549	45.8	459	38.4	189	15.8
Heavy flour	1,300	1,154	88.8	110	8.4	36	2.8
Fine flour	1,547	1,158	74.9	217	14.0	172	11.1

From the table it is apparent that the untreated plat sustained a much heavier loss than any other portion of the yard. It must be remembered in this connection that the end of the yard occupied by the unsulphured plat and the plat treated with heavy sulphur, was the part of the yard where little mildew could be found at the time of the first treatment. At that time the lower leaves of many hills in the other end of the yard were white with mildew. In fact,

until hops were in full bloom, mildew could scarcely be found in the unsulphured portion of the yard and at no time was it serious on the leaves there. It was only when the hops began to come out of blossom that the mildew began to develop rapidly in this portion of the yard, shortly outstripping the other portions of the yard.

There seems no doubt that if an untreated portion had been left in the other end of the yard the loss in it would have been total. The writer is of the opinion that the results as given in the table show a prejudice against flowers of sulphur not altogether deserved though representing the conditions at picking time very well.

Wilsey yard, Middlefield.— This yard was considered desirable for experimental purposes because for several years it had been a complete loss due to mildew and scattered spots of mildew were found throughout the yard on June 18 in the season of 1914.

This yard was located on a tableland near the summit of the hills of Middlefield in Otsego County. It was very nearly level and seemed as uniform as could be desired. The yard, which was 88 hills long and 41 hills wide, was divided into plats running crosswise with an unsulphured portion 12 hills square in the northeast corner. The three other plats of the experiment were 23 hills wide leaving a strip 19 hills wide to be sulphured by Mr. Wilsey. Beginning at the north end of the yard, the three plats were treated respectively with heavy flour sulphur, fine flour sulphur, and flowers of sulphur.

Applications of sulphur were made to this yard as follows:

TABLE VII.— SULPHURING IN WILSEY YARD, 1914.

DATE.	SULPHUR PER ACRE.		
	Heavy flour.	Fine flour.	Flowers.
	Lbs.	*Lbs.*	*Lbs.*
July 3	50	41.5	42.5
July 13	50	42.5	42.5
July 25	50	42.5	42.5
August 3	50	42.5	42.5
August 13	50	42.5	42.5
Average	50	42.3	42.5

At the time of the first treatment some increase in the amount of mildew had taken place. It still seemed to be quite uniformly distributed between the different plats. On July 13, fresh mildew was appearing. The yard was much improved on July 22. The last treatment was made after the rainy weather had begun in mid-August. Slight increases in mold continued to take place in August. On August 13, the section of the yard dusted with fine flour sulphur was clearly in much better condition than any of the other plats. Scarcely any injured hops could be found in this section of the yard, which formed a marked contrast to the plats on both sides of it.

Samples were secured from this yard on August 25. Unfortunately the writer had not been informed that the picking was to start so soon, so that the larger part of the plat dusted with flowers of sulphur had been picked before his arrival. A sample was secured from the remainder of the plat. The figures given, therefore, are not as reliable an index to the condition of this plat as are the figures for the other plats. Previous inspection indicated that this plat was most severely injured by the mildew of any of the sulphured plats, though probably not as much worse than the heavy flour plat as indicated by the table. The following table summarizes the results:

TABLE VIII.—CONDITION OF THE HOPS IN THE WILSEY YARD AT PICKING TIME, 1914.

PLAT.	Total number.	FREE FROM MILDEW		SLIGHTLY MILDEWED.		VALUELESS.	
		Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
Unsulphured	1,093	12	1.1	227	20.8	854	78.1
Flowers	644	271	42.08	305	47.36	68	10.57
Heavy flour	533	367	68.9	141	26.4	25	4.7
Fine flour	487	458	94.04	27	5.55	2	.41

It is apparent that the unsulphured portion of the yard in this case was so nearly a total loss as not to be worth picking, about 80 per ct. being worthless and only 1 per ct. free from mildew. This was markedly different, as usual, from any of the sulphured plats. The fine flour plat was between the other two plats in this case and formed, as shown by the table, a striking contrast to the sulphured plats on either side.

Lehman yard, Sharon Springs. — This yard was located near Sharon Springs on rolling land. The year previous sulphuring operations had not been successful. The crop was a complete failure. It was the intention of the writer to supervise the sulphuring here personally but this proved impossible because the numerous rains made repeated sulphurings necessary in other yards and hindered travel. Several visits were made to this yard during the summer.

A check plat ten hills square was left unsulphured in one corner of the yard. The other plats were each ten rows wide and ninety-five hills long. As this yard was at a considerable distance from Cooperstown where the weather record was made, Mr. Lehman kept his own record of the dates on which rains occurred, together with the dates on which sulphur was applied. This record is shown in the following table:

TABLE IX.— RECORD OF RAINFALL AND SULPHURING IN LEHMAN YARD, 1914.

Dates of sulphuring.	Dates of rains.	Remarks.
.....	June 7.	
June 15.		
June 29.....	July 1.....	Heavy rain.
July 4.....	July 5 and 7.....	Rain.
July 8.....	July 9.....	Very heavy rain.
.....	July 11.....	Heavy rain.
July 13.		
July 20.....	July 23.....	Rain.
July 25.....	July 29.....	Rain and hail.
July 31.....	August 1.....	Rain.
August 3.		
August 8	August 10.....	Rain.
.....	August 12.....	Rain.
August 15.....	August 14.....	Rain nearly all week.
August 22.....	August 20.....	Rain nearly all week.
.....	August 24.....	Rain.

From this table it is apparent that several of the twelve sulphurings made were followed almost immediately by rain. The only treatments not followed by rain on the first or second day after the application were those made on July 13 and 25 and on August 3. These are probably the applications on which the control principally depended. A light application made about June 15 and one on June 29 were made with flowers of sulphur uniformly to the entire field. That on June 29 was followed by a heavy rain so

probably need not be considered. The three different kinds of sulphur were used first on July 4. An estimate, based on the amounts used out of the barrels on July 14, indicated that, in the first three applications, about 125 pounds of fine flour sulphur had been used, about 130 pounds of heavy flour sulphur, and flowers of sulphur 100 pounds. At the end of the season approximately the following amounts had been used:

TABLE X — SULPHURING IN LEHMAN YARD, 1914.

PLAT.	SULPHUR PER PLAT.	
	Total.	Per application.
	Lbs.	*Lbs.*
Unsulphured	0	0
Heavy flour sulphur	300	30
Flowers of sulphur	360	36
Fine flour sulphur*	400	40

* Fifty pounds of flowers of sulphur was used on this plat for the last application.

In this yard mildew was very plentiful on June 14 and fairly well distributed, though somewhat worse in the part treated with heavy flour sulphur. On July 14, much of the mildew still appeared healthy. By August 1, however, a great improvement in the condition of the yard was noticed. At this time some sulphur was noticed on the leaves in the check plat where it had drifted with the wind. On August 25, it was apparent that very little loss would occur in any plat except the unsulphured one. Samples were collected in this yard on September 4 and an examination of the hops gave the following results:

TABLE XI — CONDITION OF HOPS IN LEHMAN YARD AT PICKING TIME, 1914.

PLAT.	Total number.	FREE FROM MILDEW.		SLIGHTLY MILDEWED.		VALUELESS.	
		Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
Unsulphured	933	78	8.3	317	34.0	538	57.7
Flowers	786	658	83.75	72	9.15	56	7.1
Heavy flour	1,004	744	74.1	134	13.35	126	12.55
Fine flour	912	747	81.9	92	10.1	73	8.0

The plat left untreated was not so badly mildewed in this case as in some of the other yards, probably because the wind happened to be right to blow the sulphur into it several times when the rest of the yard was being treated. Still, it presents a strong contrast to the rest of the yard. When observations were made on August 25 and September 4, Mr. Lehman and the writer agreed that the plat dusted with fine flour sulphur was in slightly better condition than either of the other treated plats. The writer believes it was better, but that by chance one of the samples used in the preparation of the table was not exactly representative. The difference between the two plats was not great, however, and the results as shown in the table correspond otherwise very well with field observations.

Russel yard, Milford.— This yard was considered desirable for experimental use because it consisted almost entirely of Canada red vines which is one of the varieties most susceptible to attack by the mildew. This yard has been under observation for several years. In 1911, it was a total loss from mildew. In 1912, the mildew had a good start in the yard on June 10. During that year the hop-growers of Milford formed an association with Mr. C. L. Slocum in charge to advise in control work. The fight with the mildew proved strenuous throughout the summer but ended with very little loss. The quantity of sulphur used was about three hundred pounds per acre. During the following season the conditions and results were much the same. The yard was utilized in a test of two kinds of sulphur. A plat ten hills square was left untreated. Although some sulphur drifted into this plat the loss from mildew was fully 50 per ct.

The yard is situated just outside the village of Milford. It lies on the side hill on the west side of the valley. In 1914 it was divided into three main plats with a fourth plat ten hills square in the southwest corner left untreated for a check. The first ten rows on the west side were dusted with flowers of sulphur, the next ten rows with heavy flour sulphur and the last fourteen rows on the east side with fine flour sulphur.

In an examination of this yard on June 18 no mildew was found, although one mildewed hill had been found in an adjacent yard. On making another examination on June 24, a few young mildew spots were found throughout the yard, but more numerous on the east side. A fresh crop of mildew was also found in this yard on

July 13. On July 24, the yard did not seem to have improved much as fresh mildew was still appearing to a limited extent. On August 6 the mildew seemed to be pretty thoroughly checked except in the unsulphured part of the yard where it was attacking the young hops.

The writer was present when part of the treatments were made in this yard. The others were made by Mr. Russel, alone, with his machine adjusted as nearly as possible in the same manner. The amounts of sulphur used at each application made when the writer was present will be given and the total amount of each kind used for the season. The following table gives this record:

TABLE XII — SULPHURING OF RUSSEL YARD IN 1914.

DATE.	SULPHUR PER ACRE.		
	Flowers.	Heavy flour.	Fine flour.
	Lbs.	*Lbs.*	*Lbs.*
June 27	40	30	30
July 3			
July 15	47	52	39
July 25			
Aug. 6	50	71	43
Aug. 13			
Total	304	322	237
Average	51	54	39.5

As in several other cases, some sulphur was blown into the part of the yard that was intended to be left untreated. In this case the corner of the yard that seemed the most desirable place for the check plat from the standpoint of the usual direction of the wind, could not be used because woodchucks had eaten many of the vines early in the season and the new growth of vines which came up later was thought to be more susceptible to the mildew. Little mildew was seen in the untreated portion until the middle of July. However, as usual, it rapidly increased after the young hops began to form.

Samples were collected from this yard on August 27. An examination of these hops gave the results shown in the following table:

TABLE XIII — CONDITION OF HOPS AT PICKING TIME IN RUSSEL YARD, 1914.

PLAT.	Total number.	FREE FROM MILDEW.		SLIGHTLY MILDEWED.		VALUELESS.	
		Number.	Per-centage.	Number.	Per-centage.	Number.	Per-centage.
Unsulphured.....	856	52	6.08	561	65.5	243	28.4
Flowers.....	987	848	85.9	118	12.0	21	2.1
Heavy flour.....	1,070	978	91.4	79	7.4	13	1.2
Fine flour.....	1,152	900	78.1	224	19.4	28	2.4

The unsulphured portion of the yard was not as badly mildewed as had been the case in some instances, but still presented a strong contrast to the rest of the yard. In such a yard as this, there can be little doubt that the loss would have been complete had no sulphuring been done. The check, as it was, however, presents a sufficiently strong contrast to the rest of the yard for our purposes. Between the other plats little difference could be seen by inspection. Early in the season, as previously mentioned, more mildew was present in the fine sulphur part. This was checked, however, and at picking time little mildew could be seen in any of the dusted plats. It will be noticed that the percentage of badly mildewed hops as recorded in the table varies only about one per ct. between the different samples, which is only such a variation as might be expected between two samples from the same plat. The percentage of slightly mildewed hops is against the fine flour sulphur by a small amount. No very important difference in the sulphured plats can be claimed, however. In a measure, the conditions in this yard may be considered the reverse of the conditions in the Wedderspoon and Utter yards where the mildew was thickest early in the season in the parts dusted with flowers of sulphur; but in this case it was more strongly checked.

SUMMARY OF RESULTS IN SIX YARDS.

The results of control experiments with different kinds of sulphur are brought together into one table in order that the results of the different experiments may be more readily compared and summarized. The total amounts of sulphur applied to the different plats and the number of applications for the different yards are summarized in the following table:

TABLE XIV.—SUMMARY OF SULPHUR APPLICATIONS IN PRECEDING EXPERIMENTS.

YARDS.	Number of applications.	SULPHUR PER ACRE.					
		FLOWERS.		HEAVY FLOUR.		FINE FLOUR.	
		Total.	Per application.	Total.	Per application.	Total.	Per application.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Lehman	11	360	33	300	27	400	36
King No. 3	4	277	69	.....	.....	262	65.5
Russel	6	304	51	322	54	237	39.5
Wilsey	5	212.5	42.5	250	50	212.5	42.5
Utter	4	278	69.5	276	69	191	48
Wedderspoon	5	295	59	306	61	289.5	58
Average	.....	287.7	54	291	52	265.3	48

It is apparent from the table that, while the intention was to apply the same amount of sulphur to all plats and usually about fifty pounds per application, considerable variation from this schedule occurred due to difficulty in regulating the machines. The average amounts per application are nearly the same. There was in some cases a difficulty in getting machines to apply as much of the fine flour sulphur as was applied of the coarse flour and the flowers. This should perhaps be borne in mind in considering results; i. e., if there was any advantage in amounts of sulphur used it was against the fine flour sulphur.

The following table gives a summary of the results on the yards included in the above table:

TABLE XV — SUMMARY OF RESULTS OF SIX EXPERIMENTS WITH DIFFERENT KINDS OF SULPHUR FOR THE CONTROL OF HOP MILDEW.

YARDS.	Total number hops.	FREE FROM MILDEW.		SLIGHTLY MILDEWED.		VALUELESS.	
		Number.	Per-centage.	Number.	Per-centage.	Number.	Per-centage.
Unsulphured plats.							
Lehman	933	78	8.3	317	34.0	538	57.7
King No. 3	1,601	0	0.0	68	4.25	1,533	95.75
Russel	856	52	6.08	561	65.5	243	28.4
Wilsey	1,093	12	1.1	227	20.8	854	78.1
Utter	1,567	62	3.9	587	37.5	918	58.6
Wedderspoon	770	77	10.0	315	40.9	378	39.1
Average	.....	.....	4.9	.....	33.8	.....	61.3
Probable error	.....	.....	±1.0	.....	±5.0	.....	±5.8
Sulphured with flowers of sulphur.							
Lehman	786	658	83.75	72	9.15	56	7.1
King No. 3	1,259	874	69.4	275	21.84	110	8.74
Russel	987	848	85.9	118	12.0	21	2.1
Wilsey	644	271	42.08	305	47.36	68	10.57
Utter	1,197	549	45.8	459	38.4	189	15.8
Wedderspoon	1,105	899	81.4	176	15.9	30	2.7
Average	.....	.....	68.06	.....	24.11	.....	7.83
Probable error	.....	.....	±4.9	.....	±3.9	.....	±1.3
Sulphured with heavy flour sulphur.							
Lehman	1,004	744	74.1	134	13.35	126	12.55
Russel	1,070	978	91.4	79	7.4	13	1.2
Wilsey	533	367	68.9	141	26.4	25	4.7
Utter	1,300	1,154	88.8	110	8.4	36	2.8
Wedderspoon	681	598	87.8	77	11.3	6	0.9
Average	.....	.....	82.2	.....	13.37	.....	4.43
Probable error	.....	.....	±2.8	.....	±2.0	.....	±1.3
Sulphured with fine flour sulphur.							
Lehman	912	747	81.9	92	10.1	73	8.0
King No. 3	1,119	881	78.7	217	19.4	21	1.9
Russel	1,152	900	78.13	224	19.44	28	2.43
Wilsey	487	458	94.04	27	5.55	2	.41
Utter	1,547	1,158	74.9	217	14.0	172	11.1
Wedderspoon	702	626	69.2	71	10.1	5	.7
Average	.....	.....	82.81	.....	13.1	.....	4.09
Probable error	.....	.....	±1.8	.....	±1.4	.....	±1.1

It is clear from this table that the yards used in these experiments would have been practically a complete loss if they had not been sulphured. It scarcely needs the explanation that probably in no case was the check so severely attacked as it would have been if most of the yard had not been sulphured. This, as has been previously pointed out, is because a little sulphur was blown into the check plats in nearly all cases and because in leaving a small area of this kind, frequently in a part of the yard where there was less mildew, the chance for infection was reduced.

The conditions given above should not be taken as representative of the average field, but rather of the type of field selected for this experiment. That most yards would approximate these conditions seems likely, still yards occasionally pass through the season unsulphured with little injury from mildew. On the other hand, with the exception of a few native red-vine yards, the writer knows of no instance in which an unsulphured yard has continued year after year to escape serious injury from mildew.

The experimental yards were selected, however, because they had been injured seriously by the mildew the year previous, and because some mildew was present in the spring of the current season, so that a good test of sulphuring could be expected. It is clear from the results on the check plats that where the mildew has appeared by the middle of June or earlier the loss is fairly certain to be nearly or quite total providing the normal amount of rainfall occurs.

The difference between the average results for the check plat and the average results for the plats dusted with sulphur is large enough to be decidedly significant, as is also the difference in each separate experiment. That is to say, in this, the worst year so far encountered for successful sulphuring, approximately 80 per ct. of the hops were free from mildew on the treated plats as compared with 5 per ct. on the check plats. On the sulphured plats 95 per ct. of the hops were salable. Of these 15 per ct. were slightly injured but for the most part they could not be detected in the dried sample. Though 38 per ct. of the hops on the checks are classed as salable, only 5 per ct. were free from mildew, so that the quality of these was much poorer than of those classed as salable in the case of the sulphured plats. If the whole yard had been like the check plats, they would not have been considered worth picking in most cases.

Differences between the results from the use of different kinds of

sulphur are much smaller. The very slight differences between the average results of using the heavy flour sulphur and fine flour sulphur are of no significance, inasmuch as they are smaller in each case than the probable error. A comparison of the results secured in the different fields shows that the results are sometimes slightly in favor of one kind of sulphur and at other times slightly in favor of the other. It is clear then that these experiments fail to establish any difference in value between the fine and coarse flour sulphur used for dusting hops. The only indication that fine sulphur may be better is contained in the fact that in making applications of fine flour sulphur we usually failed to apply quite as much as of the coarser or heavy flour sulphur in getting these results.

In the case of the flowers of sulphur, the average results differ more markedly from the results of the use of the other two kinds. The results for the flowers of sulphur are not uniform, however, which makes the probable error high and indicates that this average is less dependable than the others. In three cases, as previously explained, the parts of the yards treated with flowers of sulphur seemed to be slightly more subject to attack of the mildew. On the other hand, in two yards the liability to mildew was rather in the other direction. In each case this was reflected in the results, but less markedly in the cases where fine and heavy flour sulphur were applied. These results indicate that the flour sulphur of the two different degrees of fineness used in these experiments is certainly as effective for preventing the mildew as the flowers of sulphur. There is also a basis for a strong presumption that the flour sulphur is a little more effective and dependable.

SUMMARY OF ALL COOPERATIVE EXPERIMENTS.

A number of other experiments have been carried out in which either two or three kinds of sulphur were tried side by side during the years 1912, 1913 and 1914. In all, there have been made twenty-seven such experiments involving about seventy-five acres of hops scattered through several counties. In twelve of these experiments unsulphured portions were left as checks. In all cases except in the six experiments already described, determination of the results was made only by inspection of the yards at picking time. In twelve cases a record was made of the amounts of sulphur applied, dates, etc. In the rest of the experiments the sulphuring was carried out by the

growers, who applied the two or three kinds of sulphur to equal parts of the same yard in as nearly equal amounts as possible. The amounts applied were checked up from time to time to see that approximately the same amounts per acre were used on the different plats. The following table gives a summary of the amounts of sulphur used in the yards in which untreated plats were left:

TABLE XVI.—SUMMARY OF SULPHURING IN TWELVE EXPERIMENTS.

YARD.	Number of applications.	SULPHUR PER ACRE.					
		FLOWERS.		HEAVY FLOUR.		FINE FLOUR.	
		Total.	Per application.	Total.	Per application.	Total.	Per application.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
King No. 1 (1913)	3	188	63	150	50	135	45
King No. 2 (1913)	4	236	59	.....	.....	226	56.5
Wilson (1913).....	4	218	54.5	255	64	230	57.5
Russel (1913).....	6	300	50	.....	.....	300	50
Bellinger (1913)..	5	250	50	200	40	250	50
King No. 2 (1914)	3	142	47	.....	.....	139	46
Wilsey (1914).....	5	212.5	42.5	250	50	212.5	42.5
Wedderspoon (1914).....	5	295	59	306	61	289.5	58
Lehman (1914)...	11	360	33	300	27	400	36
Utter (1914).....	4	278	69.5	276	69	191	48
King No. 3 (1914)	4	277	69	.....	.....	262	65.5
Russel (1914).....	6	304	51	322	54	237	39.5
Average.....	.....	255	54	257	52	239	49.5

It is apparent that slight variations occurred in nearly all instances due to the difficulties in regulating the machines, the only constant variation being the tendency to apply less of the fine flour sulphur than of the other kinds.

In many cases it was found impossible to make any distinction between the control of the mildew on the plats treated with the different kinds of sulphur. That is, in 1912 and 1913, the control was frequently so good in sulphured parts of yards that scarcely any mildew could be found. With one possible exception, the twelve unsulphured plats developed serious losses ranging from 50 per ct. to a total loss. In the twenty-seven trials of flowers of sulphur and fine flour sulphur in the same yard, the flowers of sulphur plat

was distinctly better in only one instance, the fine flour sulphur in seven instances. In the other yards there was no appreciable difference. Of ten times that flowers of sulphur has been compared with heavy flour sulphur, the flowers of sulphur gave better results in one instance and the heavy flour sulphur in six instances, the other trials being indeterminate. In the ten trials where fine and heavy sulphur have been compared, each has appeared better three times and the other times there was no choice. Clearly these results tend to confirm the conclusion previously stated, that heavy and fine flour sulphur are of about equal value, with flowers of sulphur taking a close third place. All have proved entirely effective in the majority of cases.

OTHER CHARACTERS OF THE DIFFERENT KINDS OF SULPHUR TO BE CONSIDERED.

In a previous bulletin[33] the writer has briefly described the different kinds of sulphur and the methods of manufacture. To this only a few notes need be added now concerning some experiences since 1912.

FLOWERS OF SULPHUR.

The flowers of sulphur has been the kind most largely used in this state for treating hops. Frequent complaints have, however, been heard that certain barrels of sulphur received will not work in the sulphuring machines. During the past season such complaints were particularly frequent. In some cases several barrels of sulphur were discarded by a single grower because they could not be used. In many other cases the growers persisted in trying to use this sulphur, but were able to apply only small amounts because it would not feed through the machines, and the little that would feed through was poorly distributed. Sometimes the resulting loss was much greater than the value of the sulphur.

The writer has often roughly examined such barrels of sulphur. The color is usually dull as compared with good flowers of sulphur which is a bright yellow. Such sulphur has a tendency to pack when pressed together in the hands not noticeable in good flowers of sulphur. When put in dusting machines, it will not feed well,

[33] Blodgett, F. M. Hop Mildew. New York Cornell Sta. Bul. 328:308–309. 1913.

tending to bridge over the outlet tube and feed very irregularly. As it leaves the delivery tube, much of it is in the form of small, flaky masses which do not float well in the air; hence, it does not distribute well. In extreme cases it drops to the ground as fast as blown out, making a yellow path along the center of the row.

A decidedly acid taste was always noticed in such sulphur, while no such taste could be detected in sulphur of good mechanical condition. In order to confirm this qualitative test, samples were taken from two lots of sulphur in the poor mechanical condition mentioned above and, also, from a barrel of sulphur in comparatively good mechanical condition. These samples have been tested for acid content by M. P. Sweeney of the Chemical Department of this Station. The acid found was sulphuric acid as follows:

TABLE XVII.— ACID CONTENT OF FLOWERS OF SULPHUR.

Sample.	Condition of sulphur.	PERCENTAGE OF SULPHURIC ACID.	
		First test.	Duplicate test.
I	Good mechanical condition	0.07	0.07
II	Poor mechanical condition	1.96	1.96
III	Poor mechanical condition	1.74	1.74

It is apparent that sufficient acid was present to account for the trouble described. The presence of sulphuric acid in sulphur naturally leads to the absorption of a certain amount of moisture and thus to the aggravation of the trouble. Sifting the sulphur has been reported to make it worse, especially if done when the air is moist.

Juritz [34] has recorded trouble, which he thought was caused by the presence of moisture and the moisture in turn was condensed from the air due to the presence of a "noticeable — although very minute — quantity of sulphuric acid." Although nearly two per ct. of sulphuric acid could scarcely be considered minute, the trouble

[34] Juritz, C. F. Sulphur as a pest remedy. *Agr. Jour. Cape Good Hope* 33:723-725. 1908.

referred to above is clearly only an exaggerated form of the same condition.

No data are available as to the effectiveness of flowers of sulphur with a high acid content, but it is apparent that if it is impossible to apply it so as to get a good distribution it cannot be effective. Marcille [35] has advanced the theory that the efficiency of sulphur when used for the control of powdery mildews is due to the sulphuric acid contained, and he suggests that sulphur should be made containing larger amounts of this acid to be more effective. Clearly, this suggestion is not practicable as it is impossible to distribute satisfactorily a sulphur containing a high percentage of acid.

FLOUR SULPHUR.

A considerable amount of flour sulphur has been used in the control of hop mildew during the past two years, though not always appearing under that name. Part of this was an imported sulphur sold in bags, which was quite difficult to use because it had in many instances become packed and caked. This may have been due to the long distance that it had been transported and possibly to the moisture absorbed during an ocean voyage. At least it could not be used without a thorough sifting to break up the lumps and balls, which was difficult. As a rule this gave very poor satisfaction for the reason stated and comparatively little has been used during the past season. During the latter part of the past season no more flowers of sulphur were available on the market, so that a large part of the growers used some domestic flour sulphur at the end of the season. No complaints were heard from this sulphur in the brief time it was tried.

The fine flour sulphur used by the writer was more difficult to sift than a good quality of flowers of sulphur. It was used in both kinds of dusting machines on the market although with one of these it was not always possible to apply fifty pounds per acre even when going in every row with the feed regulating device wide open. This sulphur was, however, quite uniform in mechanical condition and could be applied much more satisfactorily than the acid sulphur above referred to. Usually some of the clots or balls of sulphur

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[35] Marcille, R. Sur le mode d'action du soufre utilsés pour combattre l'oidium. *Compt. Rend. Acad. Sci.* (Paris). 152:780–783. 1911.

were not entirely broken up by sieving or were formed afterward, but the larger part of this sulphur formed a cloud that floated especially well in the air.

The heavy or coarser sulphur used showed a much less tendency to pack, was easier to sift, and more could be applied with the types of machines in use. This kind of sulphur did not feed from machines quite as freely as the best flowers of sulphur, but no trouble was experienced in applying a sufficient quantity of it. It did not have so much tendency to form lumps as the fine flour sulphur or the flowers of sulphur with high acid content.

It should, perhaps, be here pointed out that the results of sulphuring experiments reported in this bulletin do not disprove the theories previously mentioned, i. e., that the finer sulphur should be expected to be more active. Rather, it seems that this advantage to be expected from the use of finer sulphur has been balanced by the better mechanical condition of the coarser sulphur. In comparison to the attention which has been given to the determinations of the fineness of sulphur, it seems that the physical condition of the sulphur in other respects has been slighted.

It should not be understood, however, that extremely coarse sulphur is recommended or thought desirable. The sulphur appearing under the name of heavy flour sulphur in descriptions of the experiments contained a considerable percentage of fine sulphur which was probably the more effective part, while the larger particles tended to help the sulphur retain a better mechanical condition. It is quite easily demonstrated by dusting a leaf with this heavy sulphur and then subjecting it to a light shaking, examining it before and after shaking, that only the finer particles are retained on the leaves under such conditions. Undoubtedly, then, most of the coarser particles roll off from the leaves, fall to the ground and are wasted. Though these coarse particles were absent in the fine flour sulphur, a similar and sometimes greater loss occurred through the tendency of the individual particles of this sulphur to cling together forming lumps or balls which fell to the ground. It appears, then, that with the present dusting machines, a considerable amount of sulphur is wasted and that it is more economical to waste it before considerable labor has been expended in grinding it fine.

USE OF MIXTURES OF SULPHUR AND LIME.

At Waterville, in 1911, an experiment was carried out which was designed to determine the value of a mixture of sulphur and lime as compared with sulphur alone for combating this mildew. The results of this experiment were decidedly against the use of lime with sulphur for this purpose. A brief report [36] of this experiment was made in 1913.

In 1913 it was thought desirable to repeat this experiment to check up previous results. For this purpose one of the yards on the King farm at Index was used. During the year previous this yard had been a complete loss from mildew and the mildew was found present on June 18 in 1913. The yard was divided into four plats to be treated as follows beginning on the west side:

Plat I. 7 by 27 hills, to be untreated throughout the season.

Plat II. 10 by 49 hills, to be dusted with flowers of sulphur.

Plat III. 10 by 49 hills, to be dusted with an amount of flowers of sulphur equal to that used in plat II plus an equal amount of hydrated lime, i. e., twice as much of the mixture as of sulphur used in plat II.

Plat IV. 10 by 49 hills, to be dusted with an amount of sulphur and lime mixture equal to the amount of flowers of sulphur used on plat II.

These conditions were only approximated in practice as the following table will show:

TABLE XVIII.—SULPHURING IN KING YARD NO. 3, 1913.

DATE.	SULPHUR PER ACRE.		
	Plat No. 2. Flowers of sulphur.	Plat No. 3. Sulphur and lime mixture.	Plat No. 4. Sulphur and lime mixture.
	Lbs.	*Lbs.*	*Lbs.*
June 22	49	139	41
July 3	77	119	91
July 15	78	123	99
August 5	72	101	82
August 14	98	145	108
Average	75	125	84

[36] Blodgett, F. M. Hop mildew. New York Cornell Sta. Bul. 328:298. 1913.

Of the applications made in this yard, that on August 5 was the most unfortunate, coming as it did in a critical time in the development of the hops but being followed by a heavy rain on the day following. An application on July 25 would have been more desirable.

The mildew was found in this yard on June 18 as small spots scattered pretty evenly throughout the yard and an adjoining yard. In the untreated portion of the yard the mildew increased rapidly and quite covered the leaves of most of the plants early in July, as also on scattered plants throughout the yard. In the unsulphured portion of the yard practically all of the hops failed to come out and an examination showed that the blossoms and "burs" had been infected with mildew. In the dusted portion of the yard it seemed checked at times and was at all times better than the untreated portion of the yard. The most considerable increase of mildew occurred during the last of July and first of August. Another difficulty developed in making the applications. In applying large quantities of the mixture of lime and sulphur in the center of the yard, it was found that the lime made a mixture that floated so much better in the air than the sulphur alone, that with the slight changes of the wind, it was carried through all parts of the yard in quantity. It was apparent that the strip of ten rows allowed was entirely too narrow. Thus it happened that the plat intended for sulphur alone had a considerable quantity of lime mixed with the sulphur. On the other side of the sulphur plat was the untreated plat badly infested with mildew, making the conditions very unfair for the sulphured plat.

At picking time the unsulphured plat was a total loss. There was much more difference between the two ends of the same plat than among the different dusted plats. A very large proportion of the hops on the dusted plats had been attacked by mildew during some period of their growth, and so were dwarfed or injured in some part. The yield of this yard was about half a crop, in quantity, of very poor-quality hops. The rather unsatisfactory ending of the experiment is believed to have been due principally to the influence of the lime which drifted onto the hops of the plat dusted with flowers of sulphur.

Just over a low stone fence from the yard in question was another yard (No. 4) which was dusted only with flowers of sulphur. Sulphur

was applied to the two yards on the same day in each instance and at the same rate per acre. Also mildew was found in both at the same time in the spring. It is perhaps fairer to compare the sulphur and lime dusted plats with this yard than with the sulphured plat in yard No. 3 as the lime did not drift into this yard to any considerable extent. The unsulphured plat in yard No. 4 was nearly though not quite a complete loss and therefore not quite as bad as the unsulphured plat in yard No. 3. The loss on the unsulphured portion of this yard was scarcely appreciable as compared with the loss of at least half the hops in the yard dusted with sulphur and lime.

This, together with the fact that only similarly poor control of mildew has been secured in experimental plats when the sulphur and lime mixture was previously used, indicates that lime is not a proper diluent to be used with sulphur for the control of mildew. In one plat in field No. 3, over six hundred pounds of this mixture was applied per acre or over three hundred pounds of sulphur. If we may judge by the adjoining field this should certainly have been more effective. During the season of 1914, fifty pounds less of sulphur per acre without lime has proven much more effective in the same field (Table II) under the more severe conditions of the past season, the check plat being again a complete loss.

SOME STATISTICS OF CONTROL IN HOP-GROWERS' ASSOCIATIONS.

As previously described by the writer (l. c.) local cooperative associations of hop growers were organized three years ago at Milford and Waterville. An expert was secured by each association to direct their efforts toward the control of the mildew. The writer, being charged with general oversight of these operations, has sought to obtain a fairly complete record of this work. The Milford association was discontinued at the end of one year, but the Waterville association has continued for three years. In the latter association there has been represented each year about 500 acres of hops. While the membership of the association has varied from year to year, many yards have been represented continuously throughout the three years. It seems that an analysis of the extensive experience of these associations should throw some light on the practical control of mildew.

CRITICAL PERIODS.

Some reference has already been made to the dates on which new mildew infections appeared and these are shown graphically in Fig. 1. In general it may be said that small amounts of mildew were usually found in a few yards of the association between June 10 and 15 and in a few cases earlier. With very few exceptions, all yards in the associations have had at least a small amount of mildew present by July 1. Usually there has been an increase in mildew shortly after the hops begin to grow out from the flower stage, at which time they appear to be particularly susceptible to attacks of the mildew. Thus new infections have usually been particularly heavy from August 1 to 12. These dates are only approximate, as the periods of infection appear to depend more particularly on the periods of rainfall. With the infection appearing so generally in yards before the blossoming period, it is apparent that with no protective measures, infections during the blossoming period are certain to be serious in many cases.

COMMENCEMENT OF SULPHURING.

The records of the association work show that the date on which sulphuring has been begun has varied more widely than the dates on which mildew was observed to appear. In very few instances has sulphur been applied as early as June 10. In 1912, about two-thirds of the yards had been sulphured before the first of July, while most of the remainder were treated by the tenth. In 1913, the majority of the yards had been sulphured before the first of July, and most of the remainder by the fifth. In 1914, most of the yards were not dusted for the first time until after the first of July. It was particularly noticeable that nearly all of the few failures in control, occurring particularly in 1912 and 1913, were among those who delayed sulphuring though advised to make the applications. In several of the more prominent of such instances, sulphuring was delayed till the last of July or first of August. In 1914, with extremely wet weather, a larger number of losses occurred. Many of these, though not all, could be traced to poor control during the early part of the season.

AVERAGE AMOUNTS OF SULPHUR USED.

The following table presents a summary of amounts of sulphur used per acre, the number of applications and amounts per appli-

cation for the Waterville association. The record is not complete for 1912 so that figures can be given for only part of the acreage of that year.

TABLE XIX.—SUMMARY OF SULPHURING IN HOP GROWERS' ASSOCIATION, WATERVILLE.

YEAR.	Acres.	Average weight per acre.	Average number applications.	Average weight per application.
		Lbs.		*Lbs.*
1912	299.5	165	5.2	31.7
1913	525	160.7	4.5	35.7
1914	476	249	5.6	44.5

It is apparent that in 1914, with the frequent rains, the amounts of sulphur applied were considerably increased and probably could have been profitably still further increased as there were at least a few more losses in 1914 than in previous years. These variations in the amount of sulphur necessary in different seasons are shown graphically in the curves in Fig. 2, which also give some idea of wide variation in the amount of sulphur found necessary in different yards for the same year. In a few instances no sulphur was used, while in others it was considered necessary to use over 400 pounds per acre. It seems apparent, then, that no exact rules can be made as to amounts of sulphur necessary to most economically control the mildew in all yards.

EXPENSE OF SULPHURING.

This summary indicates clearly that the application of sulphur has proven an economical means of controlling mildew. The average amounts of sulphur applied for the season per acre has been approximately 190 pounds. Assuming a cost of $2.75 per hundred pounds which is comparatively high, the average cost of sulphur per acre has been about $5.25. The cost of applying this has not been computed for the individual cases and would undoubtedly vary much depending on the size and shape of the field and many other factors. One man with a horse can, however, easily dust ten acres in a day. When a second man assists by sifting sulphur, thereby

saving delays for the driver, a larger acreage can be treated. As the average number of applications for the season is about five, it is apparent, then, that about one-half day's work for a man and horse, or perhaps $2.00, must be charged against each acre for labor. The original cost of sulphuring machines has varied from $70 to $75. They should last for several years. The amount to be charged to each acre because of depreciation in the machine should be comparatively small, so that the total average expense of sulphuring

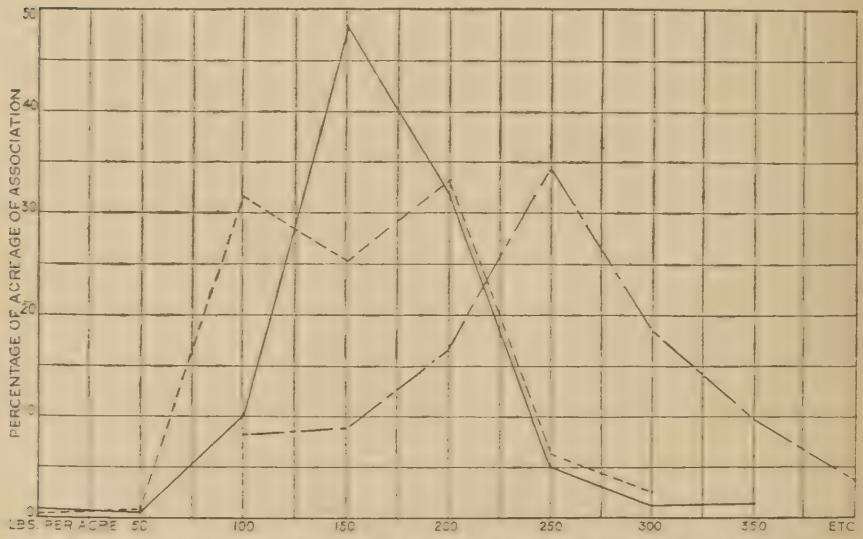

Fig. 2.—Curves Showing Amounts of Sulphur Applied per Acre in 1912 (———), 1913 (– – – –) and 1914 (– ——) by the Waterville Association. (Average amount in 1913, 160 pounds; in 1914, 250 pounds.)

has probably not been over $8.00 per acre. The average yield per acre for 1913 and 1914 in the association yards being 58 boxes or about 696 pounds per acre, the average expense of sulphuring per pound of hops raised was approximately $.0115. In other words, with hops at 25 cents per pound, it would be necessary to save 32 pounds per acre or less than five per ct. of the crop, to pay the expense of sulphuring. Obviously from the standpoint of expense this method of control may be considered practical.

ESTIMATION OF RESULTS OF SULPHURING.

Unfortunately there is no means of determining accurately the amount of hops saved by sulphuring within these associations. Approximations may be arrived at in several ways, i. e., by comparing the losses within the association with losses before sulphuring was begun or by comparing conditions in treated districts with other places. Both of these methods present difficulties. The first method is not entirely reliable because previous to the formation of the association the mildew had not become so widely distributed as later and, also, sulphuring was begun to a limited extent before the association was formed. In 1909, the mildew did serious injury in only one yard about Waterville. In 1910 it caused complete losses in parts of three or four yards. Sulphuring was begun late in the summer of 1910 in two yards. During the summer of 1911 about 50 horse-power machines besides a number of hand machines were sold for dusting hops. A considerable part of these were sold about Waterville, so that more or less sulphuring was done in 1911. Much of this, however, was done late in the season so that only part of the loss was prevented.

During the winter following, associations were organized at Waterville and Milford and question sheets were sent out to the members asking, among other things, for estimates of the losses due to mildew the year previous. For the Waterville association, 33 of the replies are available involving a total of 354 acres of hops. Of these, six acres were new fields with no crop losses. Of the remainder, the yards on six farms, involving a total of 92 acres, had been under observation by the writer and sulphured under his direction in 1911. The losses in these yards were reported as "none" or "very slight." No statement was made concerning 34 acres. Of the remaining 24 farms, involving 222 acres, 12 were reported to have been sulphured more or less. Of these 24, three reported no losses, 5 very slight losses, the remaining 16 reported losses ranging from one-fifth to the entire crop. The losses as given total approximately 57,000 pounds of hops which at the ruling price of hops that season meant a loss of $25,000 to those 24 farms.

At the end of the season of 1912, the first year of association sulphuring, a survey was made of the results on 36 farms involving a total of 300 acres. In eleven cases losses were reported as very small, while in two cases, involving 21 acres, the total losses were

estimated at about 1,000 pounds. In 1913, reports were made on 525 acres. No losses were reported on 56 out of 61 farms; slight losses were reported on three and serious losses on two. In one of these cases the loss was reported as 25 per ct. of the crop on 6 acres and was probably greater; in the other, a 40 per ct. loss of crop on 10 acres. In both cases the sulphuring had been neglected. In 1914, the final survey included 476 acres on 57 farms. No losses were reported on 33 farms; on 21 farms losses were reported as slight; and in three yards as heavy. In one case a loss estimated at 1,800 pounds occurred, apparently due to neglect of sulphuring early in the season. In a second case, where a large amount of mildew was present early, the yards were reported in good shape at picking time except one acre. In a third case but few hops were picked on a seven-acre yard which had been sulphured but not frequently or heavily enough, considering the amount of mildew present early. The yard was dusted four times using about thirty pounds per acre. This amount proved entirely inadequate.

No record has been made of the conditions in yards outside the association though the writer has had occasion to observe them for the past several years. In many cases growers not in associations have sulphured quite as thoroughly or more so than those inside. In some communities some of the leading growers began sulphuring in 1911 and were largely copied by their neighbors. In other communities, no sulphuring was done in 1911 and 1912, or only half-heartedly done. During picking time in 1912, hundreds of acres of hops never picked were seen in such neighborhoods. A few yards usually escape the mildew for a year or two without treatment, but these are rare. The result has been that in communities where sulphuring was not begun, complete losses have been the rule and it has proven necessary to abandon hop culture altogether, or adopt the treatment. One such section was particularly noticeable in the fall of 1913. Nearly two-thirds of the hop yards were not picked or only partly picked. A large part of those picked were of extremely poor quality. In the season of 1914 a great improvement was made in this same section even under the more adverse conditions. A few yards not picked were seen but these were comparatively rare as compared with the year previous.